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DETERMINATING THE ERRORS COMPENSATIONS BY USING NUMERICAL SIMULATIONS

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***Abstract**: In this paper, are presented numerical simulations results regarding the compensation of the errors. To realize that, the start point it given by the errors, which appear inevitably during the machining processes. This approach it was determinate a general and complex mathematical model for the most complex structure type 3T3R–3T3R. The model is able to calculate all generalized coordinates knowing only the initial linear and angular errors. The initial errors can be imposed or measured; it must know the size of these. This thing allows that, the next parts that will correctly and precisely machine even those was improperly positioned into fixing devices.*
***Key words:** kinematic structures, error compensation, machine tool, 3T3R structure.*

1. INTRODUCTION

The most and complex structure type 3T3R–3T3R is characterized by that, the all motions are attributed simultaneous, both positioning and orientation structure of the tool and of the piece. This model in variant without errors and with errors allows to be applied for any type of structure (728 variants possible) and is calculating the positioning and orientation of any point from the surface of the part. Also, into the mathematical model are introduced the initial errors. The model is calculated the generalized coordinates to allow to machine correctly and precisely the parts with corrections.

1.1 Cooperating general model 3T3R – 3T3R applied for a machine tool type 3T2R – 0

A major advantage of the general cooperating model with errors compensations is that, it can be applied to any kinematic configuration, with other words it can be particularized for any type of machine tools.

In this case, it is about a machine tool type 3T2R–0 (fig. 1). This is having three coordinates linear (q_1, q_2 and q_3) and the other two is for orientation, noted with q_4 and q_5 as we can see in figure 1.

The main stages of the mathematical model with errors compensations are:

- to process a part correctly without initial errors;
- to process the same part with initial errors.

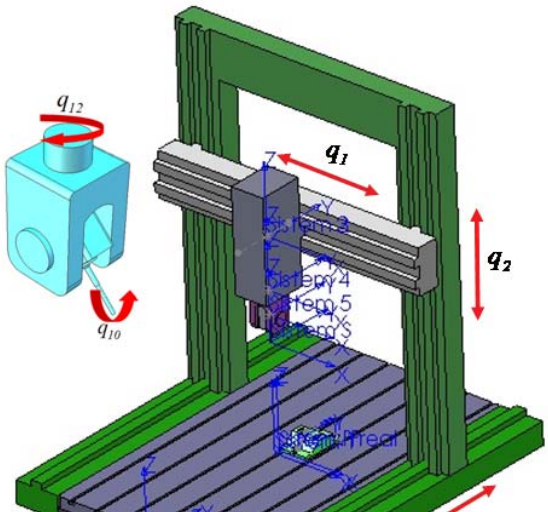

Fig. 1. The cooperation kinematic structure 3T2R – 0 in the zero configuration

In the both stages, the output dates are the coordinates generalized. In the case of machining without errors the input dates are the positioning and orientation vectors of the workpieces. In the other case, that of machining with errors beside the positioning and orientation vectors of the workpieces appears the errors. These can be imposed or measured.

The phenomenon of errors compensations is given by the fact, that knowing the initial errors, for the next parts which are machined, it will be realize correctly and without errors. The coordinates generalized are given the linear and orientation displacement along the X, Y and Z axis, necessary to machine correctly.

Also, in the both cases, the reporting of the systems is different.

In the case of the calculating of coordinates generalized without errors the reporting is made at the nominal system of the piece, noted with S_P. In the other case, with initial errors, the reporting is made on the real system of the piece, noted with S_{Preal}. Are use different type of systems because, the last one, S_{Preal} is affected by errors. These systems can be overlap or not, depending by the machining conditions.

1.2 The case of machining of workpiece without errors

To accomplish this thing, in a first step are machined some points from the piece without to introduce initial errors.

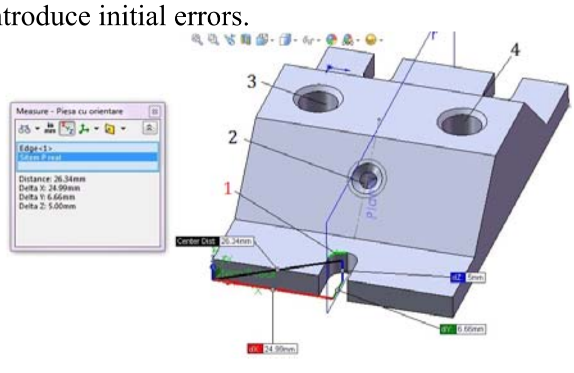

Fig. 2. Positioning and orientation coordinates for the machining point 1

Table 1

$^{(0)}X_{SP} = \begin{pmatrix} ^{P}\overline{p}_{SP} & ^{P}\overline{\psi}_{SP} \end{pmatrix}$					
$^{P}\overline{p}_{SP}$ $\langle mm \rangle$			$^{P}\overline{\psi}_{SP}$ $\langle ^{o} \rangle$		
$p_{x_{SP}}$	$p_{y_{SP}}$	$p_{z_{SP}}$	$\alpha_{z_{SP}}$	$\beta_{x_{SP}}$	$\gamma_{y_{SP}}$
24,99	6,66	5	0	0	0

The signification of the notations are:

$p_{x_{SP}}$, $p_{y_{SP}}$, $p_{z_{SP}}$ − the positioning coordinate of the tool-piece cooperation along the X, Y and Z axis;

$\alpha_{z_{SP}}$, $\beta_{x_{SP}}$, $\gamma_{y_{SP}}$ − the orientation coordinate of the tool-piece cooperation along the X, Y and Z axis;

As a remark, the positioning and orientation vectors ($p_{x_{SP}}, p_{y_{SP}}, p_{z_{SP}}$) are equivalents with dX, dY and dZ the afferent notations of the SolidWorks software.

The coordinates generalized results from the general cooperating model 3T3R–3T3R are:

Table 2

The generalised coordinates (displacements on the motor couples)				
$\langle mm \rangle$			$\langle ^{o} \rangle$	
q_1	q_2	q_3	q_4	q_5
6,66	-179	24,99	0	0

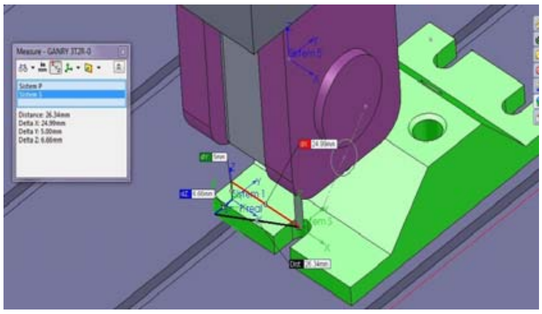

Fig. 3. The validation of the generalized coordinates for the machining point 1

To machine another point from the surface of the piece is illustrated bellow. In this case, is about a inclined hole, meaning that are necessary orientation movements.

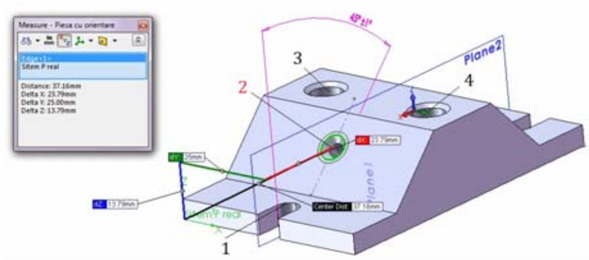

Fig. 4. Positioning and orientation coordinates for the machining point 2

The input parameters are listed in the table 3.

Table 3

$^{(0)}X_{SP} = \begin{pmatrix} ^{P}\overline{p}_{SP} & ^{P}\overline{\psi}_{SP} \end{pmatrix}$					
$^{P}\overline{p}_{SP}$ $\langle mm \rangle$			$^{P}\overline{\psi}_{SP}$ $\langle ^{o} \rangle$		
$p_{x_{SP}}$	$p_{y_{SP}}$	$p_{z_{SP}}$	$\alpha_{z_{SP}}$	$\beta_{x_{SP}}$	$\gamma_{y_{SP}}$
23,79	25	13,79	0	45	0

The output parameters are presented in the table 4. These represent the new generalized coordinates obtained from the mathematical model.

Table 4

The generalized coordinates				
$\langle mm \rangle$			$\langle ^o \rangle$	
q_1	q_2	q_3	q_4	q_5
-7,5269	-183,6830	23,79	0	45

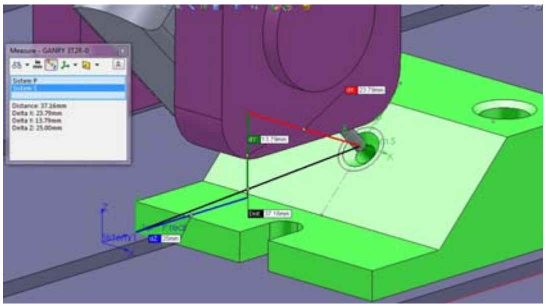

Fig. 5. The validation of the generalized coordinates for the machining point 2

As we can see, from the figures 2 and 3, respectively 4 and 5 the positioning and orientation vectors are the same after the results obtained from the general cooperating model. The generalized coordinates calculated with the general model 3T3R–3T3R are introduced into the SolidWorks where are given the same values to allow to the tool to process the machining points desired.

Having identically results, it meaning that the general mathematical model 3T3R–3T3R is validate in the case of machining without introducing initial errors (fig. 3 and 5).

1.3 The case of machining of workpiece with errors

Like in the precedent paragraph, here the input parameters are remain the same, with difference that in the mathematical model are introduced the initial errors noted with d_x, d_y, d_z the linear errors and with $\delta_x, \delta_y, \delta_z$ the angular errors. These errors can be imposed or measured; a fact important is that to know the size of the errors to determinate the generalized coordinates.

The points which it will be machined are remaining unchanged.

The parameters which must be introduced into the model are the positioning and orientation vectors and the linear and angular errors. These are represented in the figure 6 and in the table 5.

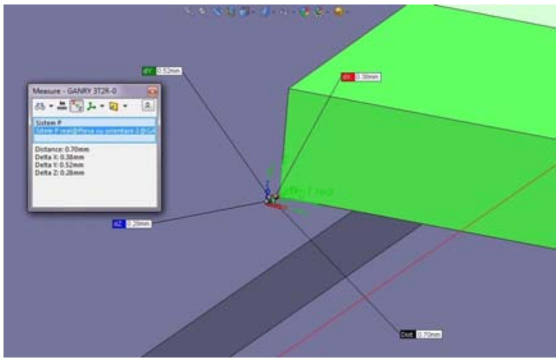

Fig. 6. The values of the initial errors for the machining points 1 and 2

As we can see from the figure 6 the new system of the part is the real system, noted with $S_{P_{real}}$. In this case, the system is overlap on nominal system of the workpiece, noted with S_P.The values of the imposed errors are listed in the table 5.

Table 5

Linear errors $\langle mm \rangle$			*Angular errors* $\langle ^o \rangle$		
d_x	d_y	d_z	δ_x	δ_y	δ_z
0,38	0,52	0,28	0	0	0,5

These errors (tab. 5) and the positioning and orientating vectors (tab. 4) are introduced in the cooperating general model 3T3R–3T3R resulting the compensating generalized coordinates, which allow to accomplish a machining process correctly and precisely. The coordinates generalized obtained from the mathematical model are presented in the table 6. These value of q_1, q_2, q_3, q_4 and q_5 represent the displacements necessary on X, Y and Z directions so the workpieces to be processed correctly even these are wrong positioned into fixing devices.

Table 6

The compensating generalized coordinates				
$\langle mm \rangle$			$\langle ^o \rangle$	
q_1	q_2	q_3	q_4	q_5
-0,738	-0,28	-0,3218	0	0

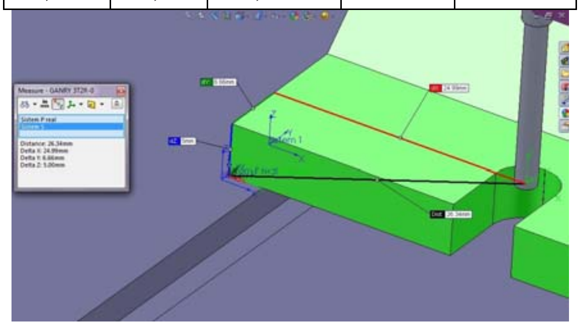

Fig. 7. The validation of the generalized coordinates for the machining point 1

For the machining point 2 the positioning and orientating vectors remain unchanged (tab. 1). Additionally into the cooperating general model 3T3R–3T3R are introduced the errors, presented in table 5.

Behind the calculus the new generalized coordinates are introduced into SolidWorks which are give the new displacements along the X, Y and Z axis in such manner that, the workpiece to be machined correctly.

The compensating generalized coordinates				
⟨*mm*⟩			⟨°⟩	
q_1	q_2	q_3	q_4	q_5
-0,728	-0,28	-0,4456	-0,5	0

In figure 8 these are identically with the positioning and orientating vectors of the workpiece, meaning that the cooperating general model 3T3R – 3T3R with errors compensation is validated (fig. 7 and 8).

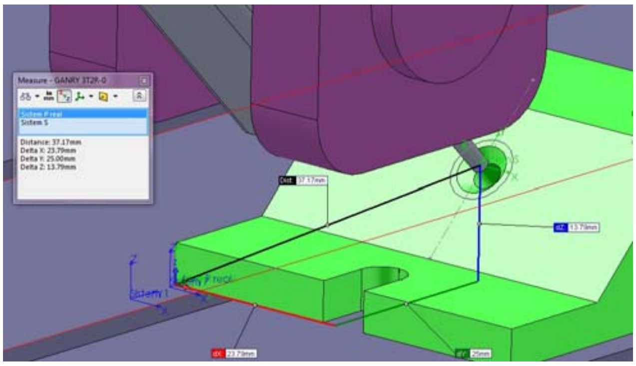

Fig. 8. The validation of the generalized coordinates for the machining point 2

3. CONCLUSIONS

The numerical analysis, in this case a particularization of the general cooperating model with errors compensation for a structure type portal 3T2R – 0, by the results obtained confirm that the general cooperating model type 3T3R–3T3R, first is work properly and the second it can be applied for any kinematic structure. The remark regarding this affirmation is to argument the dimension of values taken on the numerical simulations.

In conclusion, the general model type 3T3R–3T3R with error compensation represents an important way into the manufacturing processes because knowing the size of initial errors, even them, imposed or measured can be determinate the auxiliary displacement for the motor couples. Knowing this, the next parts, which must be process, will be correctly manufactured. Also, is allowing to realize parts correctly, precisely even these are incorrectly, and imprecise installed on fixing devices.

4. SELECTIVE REFERENCES

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Determinarea erorilor de compensare prin utilizarea simulărilor numerice

Rezumat: În această lucrare sunt prezentate rezultatele simulărilor numerice privind compensarea erorilor. Pentru a realiza acest lucru punctul de pornire este dat de erori, erori care apar în mod inevitabil pe durata proceselor de prelucrare. În acest sens a fost determinat un model matematic pentru cea mai generală □i complexă structură de tipul 3T3R – 3T3R. Modelul matematic este capabil să calculeze toate coordonatele generalizate cunoscându-se doar erorile ini□iale de pozi□ionare □i orientare. Acest fapt permite, ca următoarele piese să fie prelucrate în mod corect □i precis, chiar dacă sunt pozi□ionate imprecis în dispozitivele de fixare.

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